

neously catalysed hydrogen production (HTAS) and concepts for gas treatment (HTAS, FZJ) and a low-temperature fuel cell (Siemens) are also included. Based on the experimental results for methanol reformers, catalytic burners and gas conditioning units, the total system, a test unit and preliminary test results related to a hydrogen production capacity of 50 kW (LHV) and dynamic operating conditions is described. This hydrogen production system is aimed at reducing the specific weight combined with high efficiency for net electricity generation from methanol (about 50%) and low specific emissions. The application of palladium membranes as gas cleaning unit fulfil the requirements with high hydrogen permeability and low cost of the noble metal.

98/03230 On the comparison between a detailed turbine-generator EMTP simulation and corresponding field test results
Khodabakhchian, B. *et al.* *Electrical Power & Systems*, 1997, 19, (4), 263–268.

Under some circumstances, the machines of the LGJ generating station may be isolated from the Hydro-Quebec system, but remain connected to an unloaded transmission line. A preliminary study indicated the risk of harmonic overvoltages and a more thorough EMTP investigation was consequently performed in which the models and data were adjusted to reproduce recordings from a field test. The simulation results highlight the need for detailed modelling for similar studies. Furthermore, experience acquired during the process led to the recommendation on models and data selecting in order to guarantee more precise results. A test procedure to determine the parameters of a hydraulic turbine model is proposed.

98/03231 Detailed thermokinetic modelling of alkane auto-ignition as a tool for the optimization of performance of internal combustion engines

Faravelli, T. *et al.* *Fuel*, 1998, 77, (3), 147–155.

Applications for detailed chemical models of combustion processes in the optimal design of internal combustion engines are reported. Despite the complexity of the low-, intermediate- and high-temperature oxidation mechanisms of hydrocarbon fuels, there is a sufficiently quantitative understanding of the elementary reaction steps involved and satisfactory kinetic schemes are available, especially for alkanes. It is possible to predict typical non-isothermal phenomena such as cool flames and oscillatory behaviour and these are the basis for validation of the models. The kinetic model for alkane combustion as described and its performance tested against experiments performed in closed vessels, well-stirred flow reactors and rapid compression machines. Reaction of a fuel + air mixture at the high pressures and temperatures achieved in the cylinder of a reciprocating engine is then studied in an idealized way by considering the combustion chamber to be represented by a perfectly stirred reactor with changing volume. The results of the predicted autoignition are compared with experimental results obtained in a motored engine. Knowledge of the detailed chemistry of oxidation may be used not only for exploring engine design, but also for the new formulation of fuels and the proper understanding of the effect of gasoline additives and their effect on pollutant formation.

98/03232 Effect of combustion on the economic operation of endoreversible Otto and Joule-Brayton engine

Chandra Bera, N. and Bandyopadhyay, S. *Int. J. Energy Res.*, 1998, 22, (3), 249–256.

In order to simplify the analysis of an internal combustion engine, air-standard cycles are conceived. Air is assumed to behave like an ideal gas. In practice, air-standard analysis provides useful indication of the trends that the engine is likely to follow. Air-standard Otto and Joule-Brayton cycles are bona fide assumption and cannot represent the complex combustion process occurring in the internal combustion engines. In this paper, the complex combustion process is represented by a parameter called fuel-flame temperature. The effect of combustion on the thermo-economic performances of Otto and Joule-Brayton engines are studied. It is observed that the efficiency at maximum power is less than the Curzon-Ahlborn efficiency. The economic performance of the engine deteriorates due to combustion. The efficiency of the engine corresponds to maximum specific-power output, depends not only on the fuel-flame temperature, but also on the specific heats of the air and fuel. Ideal gas assumption of the working fluid is relaxed in this paper. Although somewhat idealized, the effect of combustion on the performance and economics of the internal combustion engines gives a reasonable design goal and better understanding of the real-heat engine.

98/03233 Effects of external boost compression on gas turbine performance in CPFBC applications

Freier, M. D. *et al.* *Proc. Annu. Int. Pittsburgh Coal Conf.*, 1996, 13, (1), 74–79.

When applied in a circulating pressurized fluid bed combustor (CPFBC), both the thermodynamic cycle and the performance of the individual components comprising the machine are affected in a commercial gas turbine designed and optimized for natural gas fuel. These effects derive from the increased pressure drop encountered between the compressor discharge and the expander inlet and from changes in gas properties and flow rates for the hot combustion products. The net effect is that power output can be reduced and significant design and/or operational compromises may be required for the gas turbine. Application of an external boost

compressor can mitigate these effects by rematching the nozzle flow relation and increasing net power without increasing the physical nozzle area of the turbine.

98/03234 Experimental and simulation analysis of the transient operation of a turbocharged multi-cylinder IDI diesel engine

Rakopoulos, C. D. *et al.* *Int. J. Energy Res.*, 1998, 22, (4), 317–331.

To study the response of a multi-cylinder, turbocharged, IDI (indirect injection) compression ignition engine, under transient operating conditions, an experimental and theoretical analysis has been conducted. To this aim, a comprehensive digital computer model is developed which solves the governing differential equations individually for each cylinder, providing thus increased accuracy over previous 'single-cylinder' simulations. Special attention has been paid for diversifying the transient operation from the steady-state one, providing improved or even new relations concerning combustion, heat transfer to the cylinder walls, friction, turbocharger and aftercooler operation, and dynamic analysis for the transient case. An extended steady state and transient experimental work was conducted on a specially developed engine test bed configuration, located at the authors' laboratory, which was connected to a high-speed data acquisition and processing system. The steady-state measurements are used for the calibration of the individual submodel constants. The transient investigation includes both speed and load changes operating schedules. During each transient test four major measurements were made continuously: engine speed, fuel pump rack position, main chamber pressure and turbocharger compressor boost pressure. The hydraulic brake coupled to the engine possesses a high mass moment of inertia and long non-linear load-change times, which, together with the indirect injection nature of the engine, are important challenges for the simulation code. Explicit multiple diagrams are given to describe the engine and turbocharger transient behaviour including smoke predictions. For all the cases examined, the agreement between experimental and predicted responses was satisfactory, proving the validity of the simulation process, while providing useful information for the engine response under various transient operations.

98/03235 Feasibility of firing an industrial gas turbine using a biomass-derived fuel

Andrews, R. C. *et al.* *Dev. Thermochem. Biomass Convers.*, 1997, 1, 495–506. Edited by Bridgwater, A. V. and Boocock, D. G. B., Blackie, London, UK.

A development programme aimed at determining the technical feasibility of utilizing a biomass-derived fuel in an industrial gas turbine engine is discussed. A flammable liquid (biofuel) derived from wood waste by flash pyrolysis is employed as the fuel, which has a heating value of ~18 MJ/kg, a density of 1.2 kg/l, and a 25% moisture content. The turbine engine selected as the test vehicle is a 2.5 MW class GT2500 engine designed and built by Mashproekt in the Ukraine. The standard operating conditions and layout of this engine provide flexibility in optimization of the combustion system to accept lower than conventional grade fuels. The characteristics of the fuel, the fuel handling system, and the results of preliminary component and engine tests are presented. Operation of the GT2500 industrial gas turbine engine was successful from idle to full power using biofuel.

98/03236 Fuel cells for vehicle applications in cars—bringing the future closer

Panik, F. *J. Power Sources*, 1998, 71, (1/2), 36–38.

The fuel cell electric propulsion system has the highest potential, among all alternative drive systems, to compete with the internal combustion engine. Daimler-Benz AG has therefore entered into a co-operative alliance with Ballard Power Systems with the aim of bringing fuel cell vehicles to the market. Apart from the fuel cell itself, fuel cell vehicles require comprehensive system technology to provide fuel and air supply, cooling, energy management, electric and electronic functions. To a large extent, the system technology determines the cost, weight, efficiency, performance and overall customer benefit of fuel cell vehicles. Hence, Daimler-Benz and Ballard are pooling their expertise in fuel cell system technology in a joint company, with the aim of bringing their fuel cell vehicular systems to the stage of maturity required for market entry as soon as possible. Hydrogen-fuelled zero-emission fuel cell transit 'buses' will be the first market segment addressed, with an emphasis on the North American and European markets. The first buses are already scheduled for delivery to customers in late 1997.

98/03237 Gas turbines

Perkavec, M. and Schmidt, R. G. *Brennst.-Waerme-Kraft*, 1997, 49, (4), 97–104. (In German)

The actual state and trends in gas turbine technology are given. Topics include assessment of compressors, turbines, combustion chambers, emissions, fuels, control and maintenance, combined processes, coal firing, and development of new materials.

98/03238 Optimum performance of irreversible Stirling engine with imperfect regeneration

Wu, F. *et al.* *Energy Convers. Mgmt.*, 1998, 39, (8), 727–732.

A Stirling engine with heat transfer and imperfect regeneration irreversibilities was subjected to an optimal performance analysis. The relationship between the net power output and thermal efficiency of the engine is

derived and detailed numerical examples are given. Performance evaluation and design modification for Stirling engines could benefit from the findings of the study.

98/03239 Prediction of mixture formation and heat-release in a turbocharged direct-injection diesel engine

Chan, S. H. and Chen, X. S. *J. Inst. Energy*, March 1998, 71, 33–46.
In order to predict the rate of heat-release in a turbocharged direct-injection diesel engine, a multi-zone combustion model has been developed. The model considers the complete air-fuel jet mixing process and temperature-dependent reaction rates in each zone; this allows the distribution of the burning rate, local temperature and equivalence ratio to be determined both spatially and temporally. The predicted combustion pressures in the closed engine cycle are validated satisfactorily by experimental results obtained from a computer-controlled engine test-bed. The extension of the model to prediction of exhaust emissions during transient engine operation is also discussed.

98/03240 Reciprocating steam engine power plants fed by woodwaste

Bidini, G. *et al.* *Int. J. Energy Res.*, 1998, 22, (3), 237–248.
Small size power plants can be operated successfully with reciprocating steam engines fed by facilitated renewable energy sources like wood waste. Until now, reciprocating steam engines have only been employed in third world countries where energy is in short supply. However, it has now become attractive to developed countries because of growing environmental sensitivity. Application to a real case shows conditions for the economic feasibility of reciprocating steam engine in comparison with the heat based or other cogeneration techniques. An economic analysis is performed by the annual equivalent method and the internal rate of return method.

98/03241 Reduction of emission from spark-ignition engines in USA and Europe

Svajgl, O. *Pet. Coal*, 1997, 39, (1), 37–40.
Emissions reduction from spark-ignition engines is reviewed in this paper. The situation in the US, the cost of refinery for emissions reduction, the benefits of emissions reduction, the effects of fuel composition on emissions from spark-ignition and diesel engines, the treatment of gasoline in Europe and the Western Europe situation are the subjects covered.

98/03242 Reduction of iron ore with coal by microwave heating

Zhong, S. *et al.* *Trans. Soc. Min., Metall., Explor.*, 1996 (Pub. 1997), 300, 174–178.
As an alternative to conventional reduction processes, microwave heating of iron ore was investigated to solve the problem of slow heat transfer. Microwave heating and reduction tests were run on composite green balls made from coal and magnetite concentrate. Both powdered and pelletized feeds were subjected to bench-scale testing using a 15 kW microwave generator, obtaining a significant increase in the reduction rate. With 20% excess stoichiometric carbon in the mix, more than 90% reduction of the iron ore can be achieved in about 10 min at temperatures of around 1000°C. The reduction of iron ore with coal by microwave heating produces a pure, dust-free, high-Btu flue gas that can be used in related thermal operations. Depending on the purity, the reduced iron product could be fed directly to an electric arc furnace for melting. It may be necessary in some cases to remove a slag phase to eliminate excess silica and alumina.

98/03243 Technical scheme and performance prediction for the gas turbine adopted in IGCC

Liu, Z. and Lin, R. *Gongcheng Rewuli Xuebao*, 1997, 18, (3), 285–287. (In Chinese)
Adopted in integrated gasification combined cycle (IGCC), a gas turbine scheme and a two-step model to predict their performance was proposed. Example calculations of practical value and data analysis are presented.

98/03244 Thermodynamics analysis of inverse cycle engine for hypersonic propulsion

Liu, X. and Zhang, S. *Gongcheng Rewuli Xuebao*, 1997, 18, (2), 145–148. (In Chinese)
As a candidate scheme for hypersonic air-breathing propulsion, the specific thrust and specific impulse of an inverse-cycle engine were analysed using a constant specific heat method and a chemical equilibrium thermodynamic method. The performance of and inverse-cycle engine was compared with that of a ramjet engine and a turbojet with an afterburner. The effect of the temperature limit of the main combustor, the temperature limit of the front combustor, equivalence ratio, turbine expansion ratio, etc., on the performance of the inverse-cycle engine were also analysed. It was concluded that in a rich fuel mode the specific thrust performance of the inverse-cycle engine was better than that of ramjet engine, especially when the Mach number is very low (<1.5) and very high (>4.5).

98/03245 The US Department of Energy—investing in clean transport

Chalk, S. G. *et al.* *J. Power Sources*, 1998, 71, (1/2), 26–35.
Together with six other federal agencies and America's three largest car makers, the US Department of Energy (DOE) is jointly investing in the development of polymer electrolyte membrane (PEM) fuel cells as a clean

and efficient technology for automotive propulsion under the Partnership for a New Generation of Vehicles (PNGV). The successful development of PEM fuel cells to meet automotive requirements is expected to extend beyond the PNGV's 2004 timeframe for achieving 80 miles per gallon in production prototypes. Given the extraordinary promise of substantial benefits to the nation in energy, environmental and economic aspects from fuel cells and other long-term technologies, the PNGV partners will continue to invest in these technologies beyond 2004. This paper describes the status of the PNGV program and the key role and technical accomplishments of the DOE Transportation Fuel Cells Programme.

11 PROCESS HEATING, POWER AND INCINERATION

Energy Applications in Industry

98/03246 Agent for improving transportation of powdered coal in furnace

Ono, R. *et al.* *Jpn. Kokai Tokkyo Koho JP 09,256,016* [97,256,016] (Cl. C21B5/00), 30 Sep 1997, Appl. 96/68,514, 25 Mar 1996, 10 pp. (In Japanese)
One or more are selected from $C_{\leq 10}$ alcohol and $C_{\leq 10}$ amine in the agent, which is applied on coal having hard groove grindability index (HGI) ≥ 30 . The fine powdered coal modified with the agent is dry at the inlet for blowing metallurgical or burning furnace. A powder prepared by pulverizing coal of HGI ≥ 30 and adding the agent on the surface and operation of furnace by using the coal is also described.

98/03247 Blast furnace process analysis using a mathematical thermochemical model

Carneiro, R. T. S. and de Paiva Giudice, F. D. *Congr. Anu. Assoc. Bras. Metal. Mater.*, 1996, 51, (1), 309–324. (In Portuguese)
Based on the Rist Diagram's theory, a mathematical thermochemical model was developed at USIMINAS Research and Development Centre in order to provide the blast furnace operator with a correct evaluation of process instability. It consists of a mass and heat balance applied to the bottom segment and to the entire furnace and evaluate the main thermochemical parameters which help to analyse and control the process. During some instability periods of No. 3 EF of USIMINAS works, a practical example of the model application is presented. The results confirmed the suitability of the method for correcting operation instabilities indicating the measures to be taken to assure an optimized BF practice.

98/03248 Characterization of pulverized and granular coal injection chars

MacPhee, J. A. *et al.* *DGMK Tagungsber.*, 1997, 9703. (Proceedings ICCS '97, Volume 2), 1311–1314.
A pilot-scale injection unit was used to examine a series of coals, ranging from sub-bituminous to low-volatile bituminous. The char reactivities were measured at conditions similar to those that would be encountered in the blast furnace raceway for both pulverized and granular chars. All the chars tested were more reactive than tuyere coke, indicating that inside the blast furnace raceway, O_2 preferentially reacts with char over tuyere coke. The injection of coal is thus beneficial in reducing coke consumption and increasing the productivity and performance of the blast furnace. Microscopic examination of the original coals and the GCI chars gave clear distinctions in maceral count in the partial transformation of coal to char during the high temperature process.

98/03249 Combustion and gasification reaction behavior of waste plastic in a blast furnace

Yamaguchi, K. *et al.* *Tetsu to Hagane*, 1997, 83, (9), 545–550. (In Japanese)
Two kinds of model experiment were used to investigate the behaviours of plastic pyrolysis, combustion and gasification reaction in order to establish the plastic injection technology in the blast furnace. The model experiments were: (1) vertical tower type reactor called the combustion model and (2) the blast furnace type reactor called the hot model. The combustion of plastic does not occur in the blast having the temperature of 1250°C and the O_2 enrichment of 0% in the blowpipe and tuyere, but it starts in the air over the temperature of 1550°C. However, the CO_2 gasification does not occur at this temperature in the combustion model. The split of plastic occurs in the atmosphere over the temperature of 2000°C in the raceway from 1000–2000 μm to 200 μm . The split plastic is burnt in the raceway, the unburnt plastic is consumed and accumulated in the hot model and it does not flow out of the top. The entering of plastic contained fines into the dead-man can be suppressed by injecting the plastic directly into the raceway through the tuyere or by keeping the distance of the lance tip from the tuyere nose as short as possible in case of the injection through the side of blowpipe.